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ON THE ANALYSIS OF CHEMICAL COMPOSITION OF MOON'S SURFACE BY DIRECT METHODS

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SUMMARY

After discussing the indirect methods applied thus far for the study of chemical composition of planet surface layers, the author refer to a new, express mothod for making such evaluations, as developed at the Ioffe Institute of Physical Engineering of the USSR Academy of Sciences. It consists in the use of a special apparatus consisting of sealed proportional counters in combination with special filters, detecting the X-ray emission of elements.

* * *

The chemical composition of a planetary body belongs to the most essential characteristics of history of its origin and evolution. Obviously, in our case the Moon constitutes an object of first priority in our program of study of the chemical composition of solar system's planetary body surfaces.

When making this investigation for the Moon, it is necessary to establish, first of all, the general correspondence in the distribution of chemical elements on its surface with that on Earth. This problem was partially resolved by Soviet scientists in indirect experiments on the study of gamma-activity [1] and of X-ray emission of the Moon [2], conducted from orbital stations, and by the efforts of American scientists having materialized the elementary analysis of a small area of the lunar surface at the landing place of "Surveyor-5" [3].

TABLE 1

CHEMICAL COMPOSITION OF THE INVESTIGATED AREA OF THE MOON'S SURFACE

Elements*	O	Si	Al	Mg	C	Na	28<A<65	Fe, Co, Ni	A>65
Atomic %	58±5	18,5±3	6,5±2	3±3	<3	<2	13±3	>3	<0,5

* The method applied allows the determination of element concentration with a given mass number A.

It may be seen from Table 1 [3] that the soil investigated by them contains above all oxygen, followed by silica and aluminum, which corresponds to the character of distribution of same elements in the Earth's litosphere. It is difficult to derive at the present time a more categorical conclusion on the adequacy of chemical composition of Earth and Moon on account of the absence of more specific data on the content of other chemical elements in the surface layer of the Moon.

The subsequent problem consists in determining whether the chemical composition of the lunar surface corresponds to either type of terrestrial rocks or meteoritic matter. Such a kind of investigations conducted over various portions of the visible and far parts of lunar surface, namely in the regions of maria and continents, craters of various sizes, "rays" etc., will yield an experimental material for a subsequent fruitful discussion of hypotheses on Moon's origin and evolution. It should be noted that the chemical analysis of lunar surface layer must be completed by soil analysis at various depths.

TABLE 2

CONTENT OF THE MOST WIDESPREAD ELEMENTS (weight %) IN COARSE TYPES OF OF ROCKS OF EARTH'S LITOSPHERE AND STONE METEORITES

Rock elements	Ultra-basic	Basic	Neutral	Acid	Sedimentary	Stone Meteorites
Oxygen	42,5	43,5	46,0	48,7	52,8	35,0
Sodium	0,57	1,94	3,0	2,77	0,66	0,7
Magnesium	25,9	4,5	2,18	0,56	1,34	14,0
Aluminum	0,45	8,76	8,85	7,7	10,45	1,30
Silica	19,0	24,0	26,0	32,3	23,8	18,0
Sulphur	0,01	0,03	0,02	0,04	0,3	2,0 *
Potassium	0,03	0,83	2,3	3,34	2,28	0,085
Calcium	0,7	6,72	4,65	1,58	2,53	1,40
Titanium	0,03	0,9	0,8	0,23	0,45	0,05
Iron	9,85	8,56	5,85	2,7	3,33	25.0 *

* Together with the iron phase of chondrites

Compiled in Table 2 are the data on the average content of the most widespread chemical elements in rocks constituting the Earth's litosphere and in stone meteorites.(These data reflect only the average concentration of elements in some coarse categories of rocks. Thus for the interpretation of experimental results one should take into account the departures from the values presented here. Not excluded is also the possibility that the measured content in elements on separate portion of lunar surface will not correspond to either of the considered categories).

Let us examine which, among the elements, are the most representative from the standpoint of our attempt to distinguish by them the various categories of rocks. In our opinion, the most widespread elements on Earth and in stone meteorites, i. e. oxygen and silica, are not the most practical in this regard inasmuch as their content is sufficiently constant in all categories of rocks. By content in sodium one may distinguish ultrabasic (0.57%) and sedimentary rocks (0.66%) from the remaining ones. To distinguish the neutral (3,0%) from acid rocks (2.77%), will apparently be impossible. A somewhat more favorable relation exists in sodium content of basic (1.94%) and neutral (3%) rocks.

Analysis of magnesium allows to determine outright to which category the rock belongs, namely to ultrabasic (25.9%), inasmuch as its content in them is higher than in other rocks by a factor of 6 - 46. Sufficiently well distinguished among themselves are the concentrations in magnesium of other rocks. Therefore, magnesium is quite convenient for the determination of specimen's belonging to either category of rocks.

A rock can be classified outright in the ultrabasic category by its low aluminum content (0.45%). However, using aluminum as a reference for distinguishing basic rocks (8.76%) from neutral (8.85%), acid (7.7%) and even sedimentary ones (10.45%) appears to be difficult.

By its potassium content one apparently may judge on sample belonging to ultrabasic (0.03%), basic (0.83%) or other rock categories. The low concentration in potassium points to its belonging to ultrabasic rocks (0.7%), a significanlly higher concentration (6.72 and 4.65%) is an indication of its belonging to basic or neutral types, while the intermediate (2.53 and 1.58%) refers the specimen to sedimentary or acid rocks. The concentration in sulphur and titanium is considerably different in various types of rocks; however, their general content is rather low (besides the anomalous case of high sulphur content in chondrites).

Finally, by iron content one may judge whether the sample belongs to ultrabasic and basic rocks (9.85 and 8.56%), to neutral (5.85%), or acid and sedimentary rocks (2.7 and 3.33%). Therefore, one should refer magnesium, potassium, calcium, sulphur and iron to the number of the most <u>representative</u> elements (for more details see [4]).

The (α,α)- and (α, p)-reaction method*, utilized in the work by the American team, does not allow us to determine the concentration of each of the most representative elements in complex mixtures of unknown composition (which are characteristic of planetary body surfaces), at least in the contemporary form of their operation. This circumstance prevented the authors of [3] to refer with a greater unambiguity the rock of the investigated area to specific category, though their data respond to the fullest extent to the composition of basic rocks; the results of the analysis partially correspond to neutral, sedimetary and acid rocks, while the concentration of groups of neutral and heavy elements point to the possibility of the presence of introduced meteoritic material. Note that according to the results of interpretation of gamma-ray spectra obtained from AMS "LUNA-10" [1], acid rocks were rejected.

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* for more details refer to [6].

Analysis of comparative characteristics of contemporary methods of determination of matter's chemical composition applicably to the study of some areas of Moon's and other planets' surfaces has indicated [4, 7] that, considered from the standpoint of clarity and expressiveness of the information provided, the possibilities of the roentgen-isotopic spectro-chemical analysis are of special practical interest. Such an X-ray isotopic fluorescent method has been put in practice at the Ioffe Institute of Physical Engineering of the USSR Academy of Sciences and applied for the analysis of basic rock forming chemical elements in unprepared surfaces [8,9].

Radioactive sources were used in the apparatus thus worked out for the excitation of characteristic X-ray emission of chemical elements present in the soil. In order to detect the characteristic emission, sealed-off proportional counter of soft X-rays were used. The utilization of proportional counters in combination with characteristic filters (potassium, silicium, magnesium etc.) provides the possibility to determine the concentration of various elements, including the most representative ones, say, magnesium, potassium, calcium sulphur and iron.

The above method and appartus can be utilized for conducting express-analysis of the chemical composition of the surfaces of the Moon, Mars, Venus and other planetary bodies of the solar system.

In conclusion, we deem it our assumed duty to extend our thanks to V. V. Petrov Yu. N. Starbunov for constructive discussions and comments relative to questions of the current work.

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